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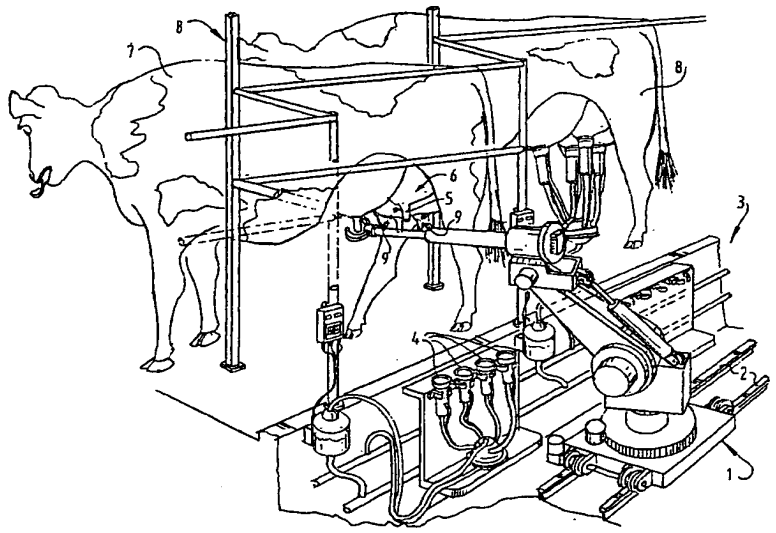
(54) Title: MILKING SYSTEM WITH THREE-DIMENSIONAL IMAGING




(57) Abstract: The invention relates to a method for automatically milking livestock, comprising of determining at least the location of teats on an udder with imaging; arranging teat cups on the teats at the determined location with a robot arm; and milking the livestock with a control of the teat cups, wherein the imaging comprises of: obtaining at least two substantially independent images having therein at least one common reference element; sending the images to an image-processing device; obtaining a three-dimensional udder pattern from the images by means of image-processing on the basis of the reference element; and driving the robot arm to the teats on the basis of the udder pattern.

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# MILKING SYSTEM WITH THREE-DIMENSIONAL IMAGING

The present invention relates to a method and milking system for automatically milking livestock, respectively comprising of determining at least the location of teats on an udder with imaging, arranging teat cups on the teats at the determined location with a robot arm; and milking the livestock with a control of the teat cups, and driving the robot arm toward the teats on the basis of formed images, and wherein the milking system comprises: at least two teat cups, a robot arm for arranging the teat cups on the teats of an udder of a livestock animal positioned at a milking location, and an imaging system for determining at least the location of one or more than one teat from formed images, and a control for driving the robot arm to the teats on the basis of the formed images.

The known method and device have the drawback that they are slow. Obtaining a location to which the milking robot must be driven in order to arrange these teat cups on the teats takes much too long. The imaging techniques which are used moreover allow too many errors, which is a further drawback.

The invention has for its object to partly, and preferably wholly, obviate the above stated drawbacks of the known art, for which purpose a method is provided which is distinguished by obtaining at least two substantially independent images having therein at least one common reference element, sending the images to the image-processing device and obtaining a three-dimensional udder pattern from the images for driving the robot arm by means of image-processing on the basis of the reference element; and which milking system is distinguished by at least one camera for obtaining at least two substantially independent images having therein at least one common reference element, and an

image-processing device for obtaining a three-dimensional udder pattern from the images for the purpose of the control by means of image-processing on the basis of the reference element.

Teats of the udder are easily identifiable by providing a three-dimensional udder pattern. By subsequently deducing control information for the robot arm from the three-dimensional udder pattern, a rapid and reliable solution is provided for localizing at least the position of the relevant teats and preferably also the orientation thereof so as to enable arrangement of teat cups with the robot arm.

In a preferred embodiment the method comprises of combining the images and herein placing the reference point in register in order to obtain the three-dimensional udder pattern herefrom. For this purpose the reference point can be made identifiable in the different images in diverse ways. A light source can thus be used to form a brightly illuminated dot on the relevant udder which can then be identified in both images of the udder. In this manner it is possible to place the reference points in register in the images. Use can be made according to the method of one camera, which is then displaced between obtaining the substantially independent images and redirected to the presumed location of the udder, or two cameras can be used.

In another preferred embodiment the method comprises of placing the camera at a distance and carrying an image for recording to the camera using a light conductor. Irrespectively of whether one or two cameras are used, the object here is that the images are as independent as possible. When the images are obtained from positions at angles of view which enclose a spatial angle of 90°, as much information as possible about the udder pattern is obtained with the images. The udder pattern is then for instance a relief map or contour map

in which the teats are clearly identifiable. Such a relief image is preferably generated from independent images with an overlap of for instance 60-80%.

The camera(s) is or are preferably disposed at a distance from the milking location. At the desired positions from which images of the udder must be obtained under the above stated conditions and preferred circumstances, it is then only necessary for instance to arrange lenses wherein light conductors extend between the lenses and the actual cameras. The cameras can be CCDs. Thus is ensured that a restless animal cannot damage the cameras, but only the simple lenses, which can be replaced at low cost if the restless animal steps against them.

The invention will be further elucidated hereinbelow on the basis of a number of embodiments as shown in the drawing, in which:

fig. 1 and 3 show a perspective view of a milking system according to the present invention, in which the method is also implemented;

fig. 2 shows a perspective view of an alternative device; and

fig. 4 shows a second alternative embodiment relative to fig. 2.

Fig. 1 shows a part of a milking parlour in which an industrial robot 1 is disposed. Robot 1 is situated for travel on rails 2 in a milking pit 3, through which the farmer traditionally walked in order to arrange the teat cups, this now being done with industrial robot 1.

As already noted, robot 1 arranges teat cups 4 on teats 5 of udder 6 of a cow 7 standing in a milking box 8. Robot 1 can travel in order to arrange teat cups 4 in diverse milking boxes 8.

As described in more detail hereinbelow and in fig. 2-4, robot 1 is provided with at least one camera 9; in the case shown in fig. 1 two cameras are arranged. The cameras can for instance be of the CCD type, although

other imaging devices are also possible, insofar the signals originating therefrom can be processed by a control 10 as shown schematically in fig. 2.

As shown in fig. 2, two images of the udder are obtained substantially simultaneously at angles of view enclosing a spatial angle α. In order to enable the collection of as much information as possible about the shape of the udder, the position of the teats, the orientation of the teats and so on, the obtained images must be as independent as possible. For this reason the spatial angle α enclosed between the directions of view amounts preferably to at least approximately 90°.

Further shown in fig. 2 is that only lenses 11 are arranged on arm 12 of the robot, and that cameras 9 are placed at a distance. Light conductors 13 are arranged between lenses 11 and the actual cameras 9. Damage to the relatively expensive cameras 9 by a restless animal for milking is effectively prevented with such a configuration. Light conductors 13 can for instance be glass fibre cables.

Fig. 2 further shows that a light source 14 is arranged on arm 12. Light source 14 illuminates a reference point 15 which is identifiable in both images of cameras 9. With this reference point 15 in both images of cameras 9 a three-dimensional udder pattern can be deduced using an image-processing program in control 10. The three-dimensional udder pattern is generated by the control in the form of for instance a relief map or contour map. It is noted in this respect that the arrangements shown in the figures are schematic, since it must be possible to map the whole udder with one set of images. The cameras 9 (or lenses 11) used are placed at a distance from the presumed location of udder 6 such that such an imaging is possible. A stereoscopic image of udder 6, and more particularly the teats 5 thereof, is thus generated with the two cameras (or lenses).

As will be apparent from the foregoing, control 10 comprises an image-processing device for obtaining the three-dimensional udder pattern. Control 10 also provides the driving of robot 1 for the purpose of arranging teat cups 4 on the teats. For the purpose of a clear view in the drawing, the robot 1 does not carry a teat cup 4. It is on the other hand advantageous to have a teat cup at the ready at the time of the imaging. In this way little time need elapse between forming of the images and the arranging of teat cups 4 on teats 5, so that there remains only a limited chance of the cow moving, which will necessitate a new imaging.

Fig. 3 shows the embodiment of fig. 1 in more detail, wherein cameras 9 are arranged directly on robot arm 12. Cameras 9 can herein be directed, this being indicated with double arrows A. An extendable part 16 of robot arm 12 is further provided, with which the distance between cameras 9 can be varied. In the embodiment shown here an optimally flexible configuration is obtained by variation of the distance between cameras 9 with part 16 and the adjustment of the associated angles of view along arrows A. Adjustment of cameras 9 and extension of part 16 of robot arm 12 are carried out by control 10 (not shown in fig. 3). A configuration similar to that of fig. 2 is of course possible, wherein cameras 9 are not placed on the robot arm, but at a distance.

Fig. 4 shows an alternative embodiment with a single camera 9 on the extendable part 16 of robot arm 12. The extendable part is displaceable in the direction of arrow B. The single camera is again adjustable, i.e. the angle of view thereof is adjustable. In a retracted position of the extendable part 16 of robot arm 12 the camera 9 is directed forward relative to robot arm 12, as shown here with dash-dot lines. Conversely, camera 9 is directed to the rear relative to robot arm 12 in the extended position of extendable part 16. Two successive

images can thus be obtained in a very short time with a single camera 9, with only a very limited risk of the relevant animal moving in the meantime. The embodiment of fig. 4 is different from the foregoing embodiments in that only a single camera 9 is provided, which must obtain two successive images. Although between obtaining of the images some time elapses during which an animal for milking could move, only a single camera 9 is required in this embodiment of fig. 4, which represents a saving relative to the foregoing embodiments.

The extendable part 16 of robot arm 12 thus forms displacing means for displacing the camera, as well as a carrier for placing the single camera.

In the embodiments of fig. 3 and 4 the reference point 15 is furthermore not an explicitly illuminated point, but another clearly identifiable element in both images. A discolouration of the skin, an abrupt bend in a blood vessel lying close to the surface of the skin, and so on can be envisaged here. In the embodiment of fig. 3 and 4 no separate light source is therefore provided for the reference point, although a separate light source (not shown) can still be provided to illuminate the whole udder.

Many alternative and additional embodiments are possible within the scope of the present invention as defined in the appended claims. Both or all cameras can be in stationary disposition relative to each other in an embodiment with two or more cameras. More than two images can also be used, and more than one reference point can be used in the images to combine the images into the desired three-dimensional udder pattern so as to enable deducing therefrom of the position and optionally also the orientation of the different teats. In addition, cameras can be used other than the stated cameras of the CCD-type. If more than two cameras are used, it is still recommended to keep the directions of view as independent as possible.

In the foregoing an industrial robot is used by way of example in each case. Other milking robots of a more conventional type can also be used to apply the present invention. The invention can further be applied with animals other than cows, such as goats and sheep and so on. Displacing means other than an extendable part of the robot arm can also be used in the embodiments of fig. 3 and 4. Displacement of the camera over the robot arm can for instance be envisaged along for instance a guide rail or a similar configuration. It is thus apparent that many alternative and additional embodiments will occur to the skilled person after examination of the foregoing.

The embodiments of the invention explicitly described above and shown in the drawings are therefore not definitive, but the invention is limited solely to the definition according to the appended claims.

## CLAIMS

1. Method for automatically milking livestock, comprising of determining at least the location of teats on an udder with imaging; arranging teat cups on the teats at the determined location with a robot arm; and milking the livestock with a control of the teat cups, wherein the imaging comprises of: obtaining at least two substantially independent images having therein at least one common reference element; sending the images to an image-processing device; obtaining a three-dimensional udder pattern from the images by means of image-processing on the basis of the reference element; and driving the robot arm to the teats on the basis of the udder pattern.

2. Method as claimed in claim 1, comprising of combining the images and herein placing the reference point in register in order to obtain the three-dimensional udder pattern herefrom.

3. Method as claimed in claim 1 or 2, wherein obtaining the images comprises of: activating at least one camera.

4. Method as claimed in claim 3, comprising of activating substantially simultaneously two cameras directed at an angle known beforehand relative to each other.

5. Method as claimed in claim 4, comprising of activating one camera at least twice in succession.

6. Method as claimed in claim 5, comprising of displacing the camera between obtaining the images.

7. Method as claimed in claim 5 or 6, further comprising of displacing the camera over a known distance and, prior to recording of an image, redirecting the camera to the presumed location of the udder in order to obtain at least two images at an angle known beforehand.

8. Method as claimed in any of the foregoing claims 3-6, comprising of placing the camera at a distance and carrying an image for recording to the camera using a light conductor.

9. Milking system for implementing a method as claimed in one or more than one of the foregoing claims for substantially automatic milking of livestock, comprising: at least two teat cups; a robot arm for arranging the teat cups on teats of an udder of a livestock animal positioned at a milking location; and an imaging system which comprises: at least one camera for obtaining at least two substantially independent images having therein at least one common reference element; an image-processing device for obtaining a three-dimensional udder pattern from the images by means of image-processing on the basis of the reference element; and a control for driving the robot arm to the teats on the basis of the three-dimensional udder pattern.

10. Milking system as claimed in claim 9, wherein the imaging system comprises at least two cameras which are arranged directed at an angle known beforehand.

11. Milking system as claimed in claim 10, wherein the angle amounts to at least approximately 90°.

12. Milking system as claimed in claim 9 with one camera, wherein the imaging system comprises a carrier for the camera, which carrier comprises displacing means for displacing the camera in the period between recording successive images of the udder.

13. Milking system as claimed in claim 12, wherein the carrier or the camera comprises directing means with which the camera can be directed to a location known beforehand of the udder of a relevant animal.

14. Milking system as claimed in one or more than one of the foregoing claims 9-13, wherein the camera is disposed at a distance from the milking location.

15. Milking system as claimed in claim 14, wherein a light conductor directed or to be directed at the location of the udder is arranged in the vicinity of a presumed location of the udder of an animal for milking, which light conductor extends to the camera at a distance from the milking location.

16. Milking system as claimed in claim 15, wherein an imaging element, such as a lens, is arranged on the end of the light conductor directed or to be directed toward the udder at the presumed location.

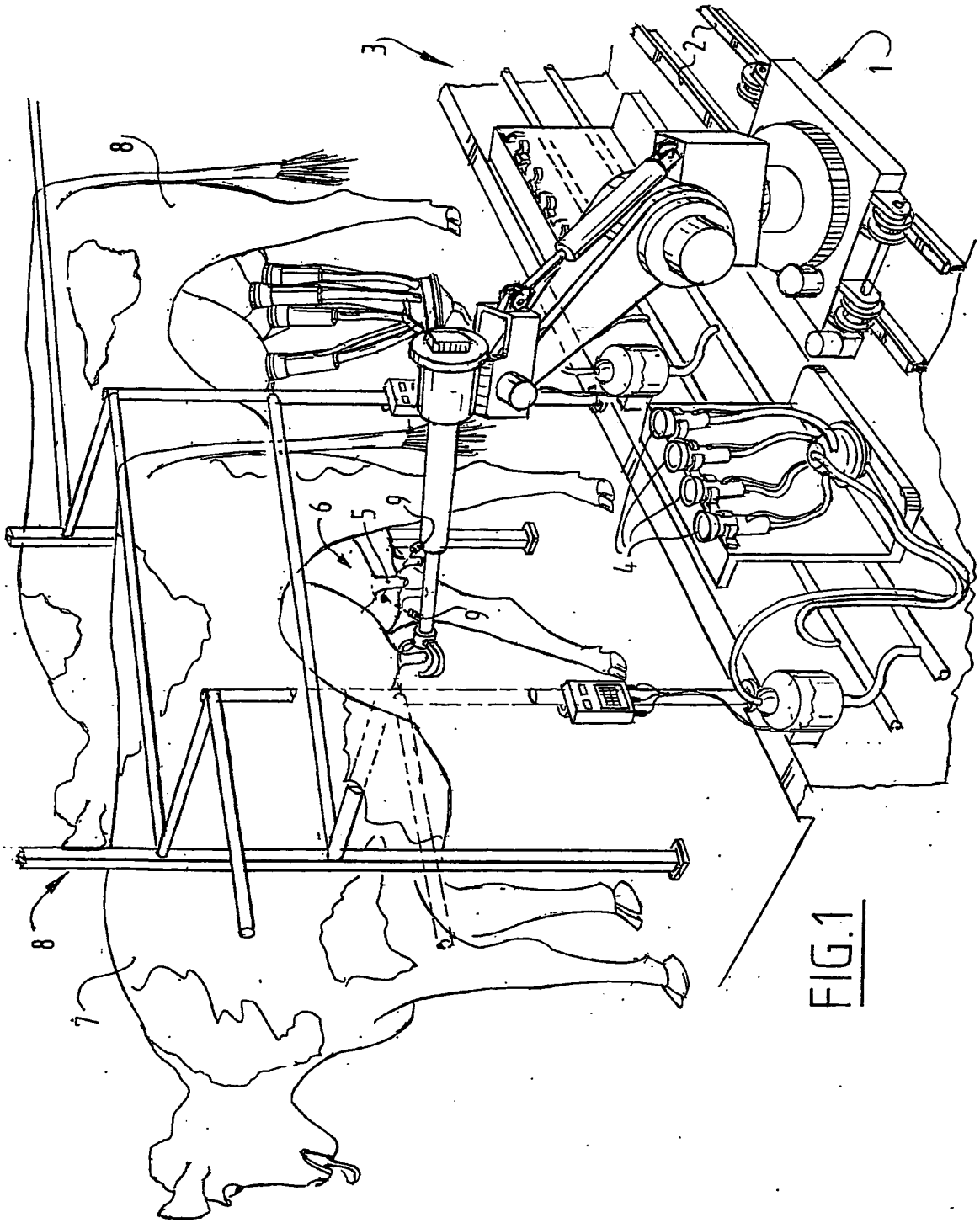


FIG.1

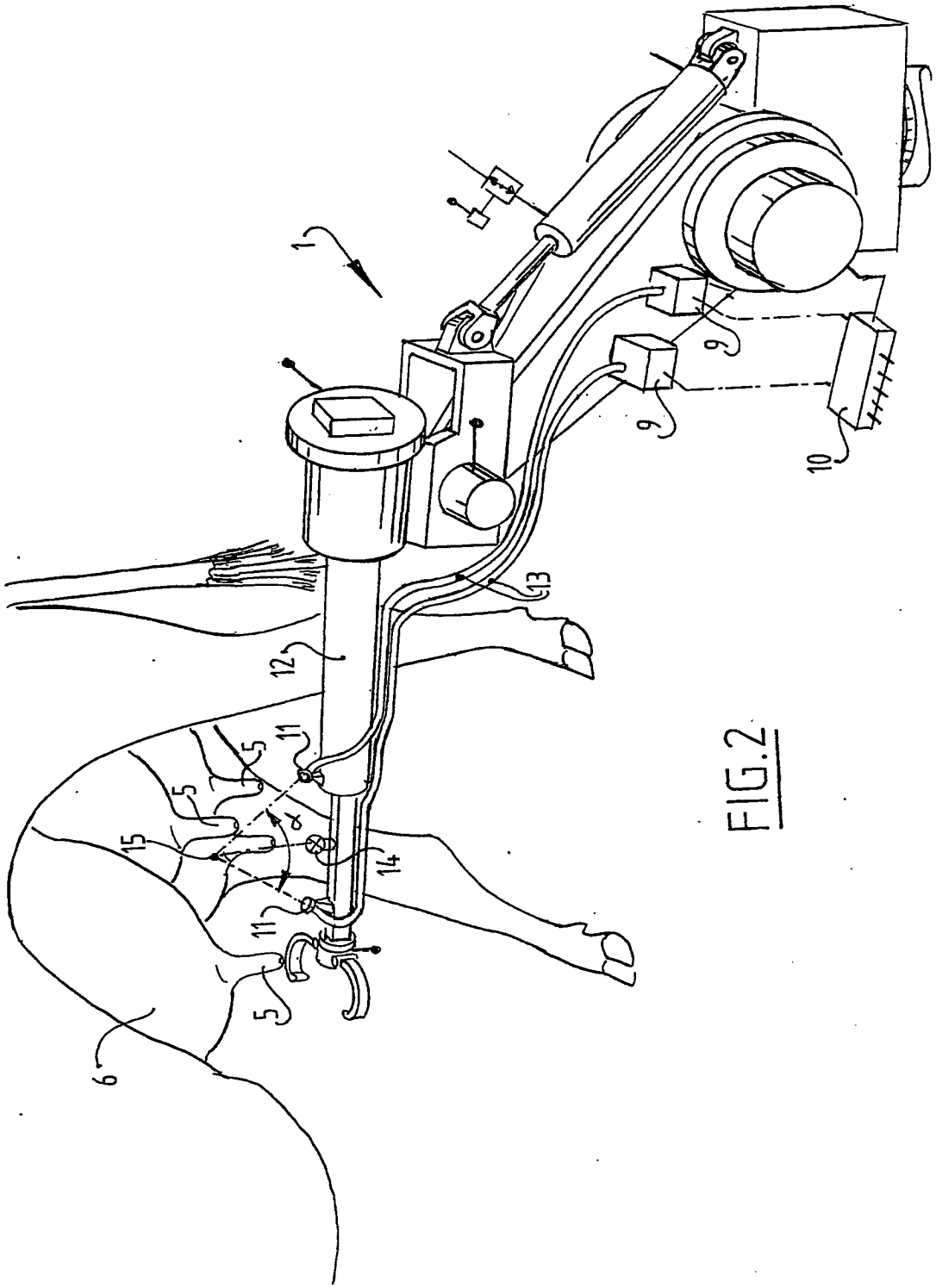


FIG.2

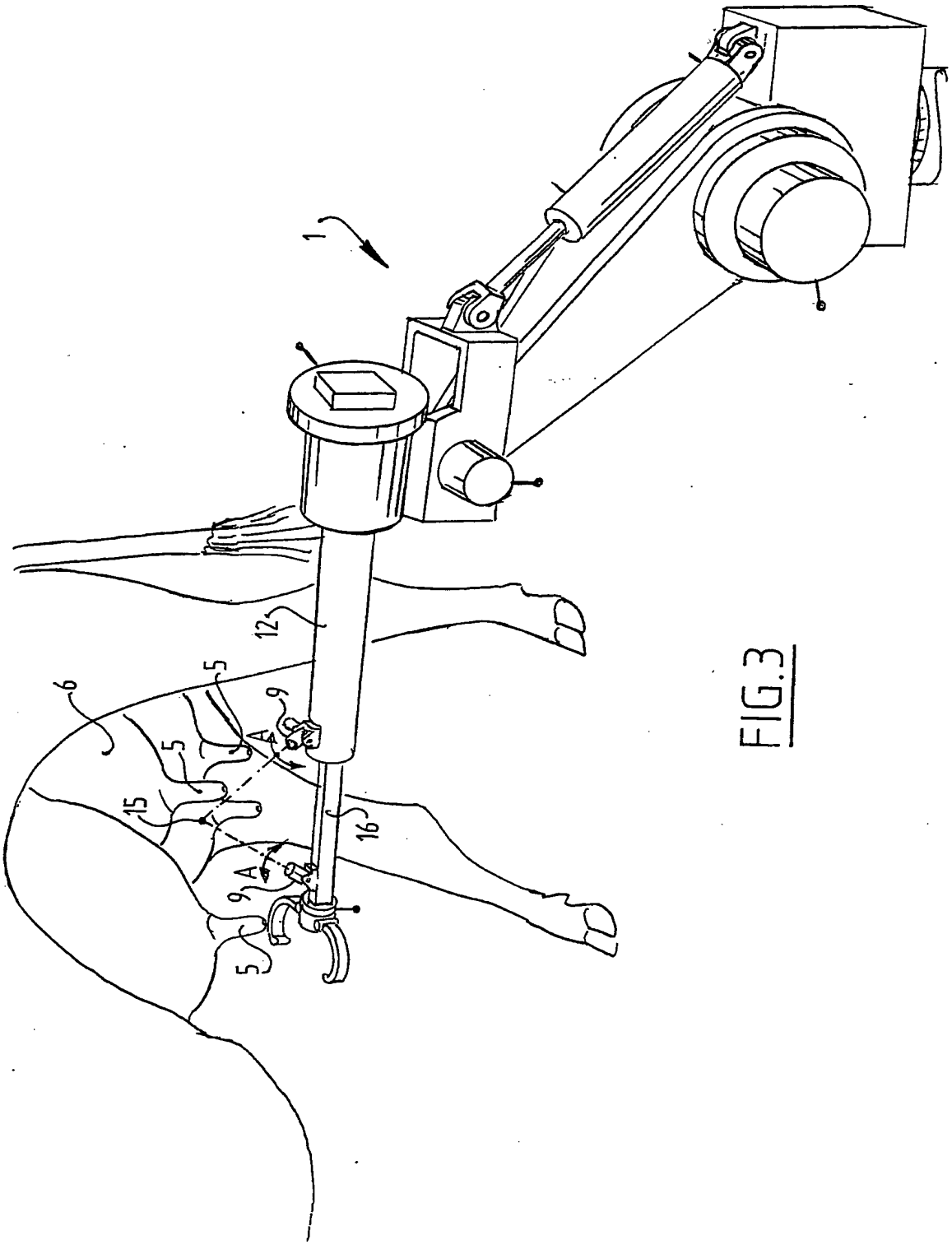


FIG.3

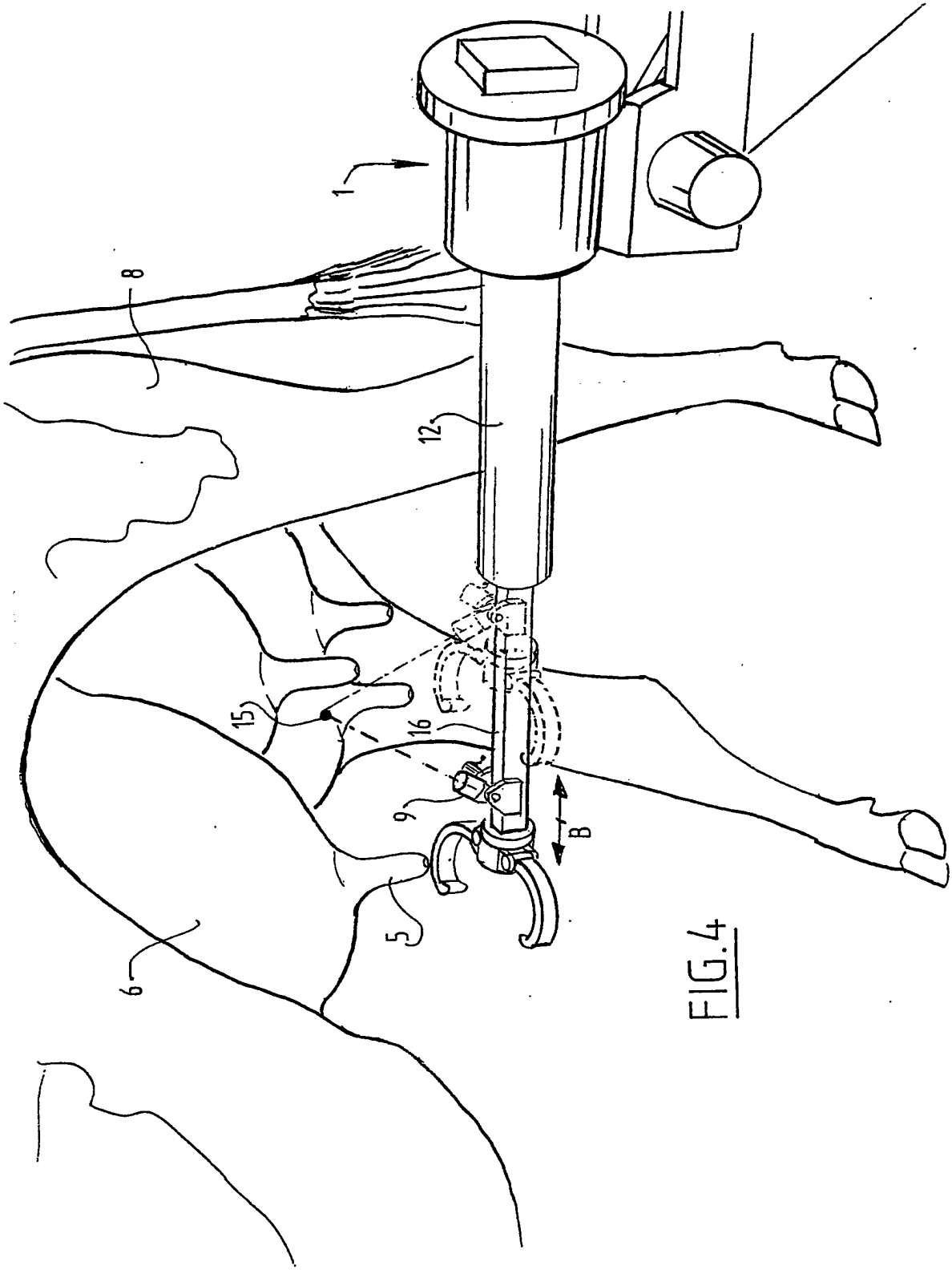


FIG.4

# INTERNATIONAL SEARCH REPORT

International Application No
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A. CLASSIFICATION OF SUBJECT MATTER
IPC 7 A01J5/017

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)
IPC 7 A01J

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practical, search terms used)
EPO-Internal, WPI Data, PAJ

C. DOCUMENTS CONSIDERED TO BE RELEVANT

| Category * | Citation of document, with indication, where appropriate, of the relevant passages | Relevant to claim No. |
|---|---|---|
| X<br>A | WO 98 19520 A (MAASLAND NV ;BERG KAREL-VAN DEN (NL); TEN CATE WALTER ENNO MARIA ()<br>14 May 1998 (1998-05-14)<br>page 2, line 10 - line 26<br>page 10, line 1 - line 32<br>claims; figures | 1-7,9,10,13<br>11,12 |
| X | WO 99 03064 A (BIRK UZI ;ALFA LAVAL AGRI AB (SE)) 21 January 1999 (1999-01-21)<br>column 6, line 14 -column 7, line 11<br>claims; figures | 1-4,9,10,14-16 |
| X | DE 37 42 867 A (FRAUNHOFER GES FORSCHUNG)<br>6 July 1989 (1989-07-06)<br>column 1, line 33 -column 2, line 35<br>claims; figures | 1-4,9,10 |

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[X] Further documents are listed in the continuation of box C.

[X] Patent family members are listed in annex.

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| Date of the actual completion of the international search | Date of mailing of the international search report |
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| Name and mailing address of the ISA | Authorized officer |
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| European Patent Office, P.B. 5818 Patentlaan 2<br>NL - 2280 HV Rijswijk<br>Tel. (+31-70) 340-2040, Tx. 31 651 epo nl,<br>Fax (+31-70) 340-3016 | Piriou, J-C |

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# INTERNATIONAL SEARCH REPORT

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C.(Continuation) DOCUMENTS CONSIDERED TO BE RELEVANT

| Category ° | Citation of document, with indication, where appropriate, of the relevant passages | Relevant to claim No. |
|---|---|---|
| X | WO 98 07311 A (STARKHAMMAR JOHANNA ;ISAKSSON ANDERS (SE); ALFA LAVAL AGRI AB (SE)) 26 February 1998 (1998-02-26) page 6, line 12 -page 8, line 4 claims; figures | 1-4,9,10 |

Form PCT/ISA/210 (continuation of second sheet) (July 1992)

# INTERNATIONAL SEARCH REPORT

Information on patent family members

International Application No
PCT/NL 01/00471

| Patent document cited in search report | Publication date | Patent family member(s) | Publication date |
|---|---|---|---|
| WO 9819520 A | 14-05-1998 | AU 729626 B2 | 08-02-2001 |
| | | AU 5883298 A | 29-05-1998 |
| | | EP 0883337 A1 | 16-12-1998 |
| | | WO 9819520 A1 | 14-05-1998 |
| WO 9903064 A | 21-01-1999 | AU 8365498 A | 08-02-1999 |
| | | EP 0993655 A1 | 19-04-2000 |
| | | WO 9903064 A1 | 21-01-1999 |
| DE 3742867 A | 06-07-1989 | DE 3742867 A1 | 06-07-1989 |
| WO 9807311 A | 26-02-1998 | AU 3713697 A | 06-03-1998 |
| | | EP 0924982 A1 | 30-06-1999 |
| | | JP 2000516814 T | 19-12-2000 |
| | | WO 9807311 A1 | 26-02-1998 |
| | | US 6167839 B1 | 02-01-2001 |